

## Chlorophyll *a* Content in the Indian Sector of the Antarctic Ocean

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南極海インド洋区のクロロフィル *a* 量

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**要旨:** 1979年12月から1980年3月まで、水産庁開洋丸により、南極海調査航海が実施され、その際、海水中のクロロフィル *a* 量の測定を行った。

フリマントル～61°S, 100°E間の往路(1/7～1/15)と61°S, 120°E～メルボルン間の復路(1/27～2/8)では表面海水中のクロロフィル *a* 量を測定した。往路、復路のクロロフィル *a* 量はそれぞれ 0.05–0.44 mg/m<sup>3</sup>, 0.02–0.18 mg/m<sup>3</sup>を示し、復路に比べ、往路の方が高い値を示した。

61°S以南100°–120°Eの調査水域では5本の測線にそった36点において表層から200m層までの10層のクロロフィル *a* 量を測定した。調査水域のクロロフィル *a* 量は0.00–0.95 mg/m<sup>3</sup>の範囲を示し、特に0.5 mg/m<sup>3</sup>以上の水塊が亜表層にコア状に分布していた。そしてそのクロロフィル *a* 極大は、ほとんどの地点で密度躍層付近で観測された。

**Abstract:** Measurement of chlorophyll *a* in the Indian sector of the Antarctic Ocean was carried out during the cruise of R.V. KAIYO MARU of the Fisheries Agency, from December 1979 to March 1980.

The chlorophyll *a* content in the surface water was measured at stations from Fremantle to the station of 61°S, 100°E (1/7–1/15, 1980) and from the station of 61°S, 120°E to Melbourne (1/27–2/8, 1980). The surface water chlorophyll *a* content in the former course ranged from 0.05 to 0.44 mg/m<sup>3</sup>, and in the latter it ranged from 0.02 to 0.18 mg/m<sup>3</sup>. Surface water chlorophyll *a* was larger on the outward leg than on the homeward leg.

The chlorophyll *a* content at 36 stations which were arranged along five transections in the survey area was measured on water samples taken from 10 layers between the surface and the depth of 200 m. The chlorophyll *a* content ranged from 0.00 to 0.95 mg/m<sup>3</sup>.

The water mass which contained more than 0.5 mg/m<sup>3</sup> chlorophyll *a* could be regarded as a core in the subsurface water. The chlorophyll *a* peaks were observed near the pycnocline at most of the stations.

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## 1. Introduction

From December 12, 1979 to March 8, 1980, R. V. KAIYO MARU made a cruise of the Indian sector of the Antarctic Ocean as part of the BIOMASS program. The chlorophyll *a* content in the surface water was measured on the outward leg from Fremantle to the station of 61°S, 100°E (1/7–1/15, 1980) and on the homeward leg from the station of 61°S, 120°E to Melbourne (1/27–2/8, 1980). The vertical distribution of chlorophyll *a* was investigated in the survey area bounded by 61° and 65°S parallels and 100° and 120°E longitudes.

There are many reports on the chlorophyll *a* content in the Indian sector of the Antarctic Ocean (ICHIMURA and FUKUSHIMA, 1963; SAIJO and KAWASHIMA, 1964; EL-SAYED and TURNER, 1977; PLANCKE, 1977). However, reports on the vertical distribution of chlorophyll *a* in this region are few (EL-SAYED and TURNER, 1977). The purpose of the present paper is to describe the results of the surface and vertical observations of chlorophyll *a* along the

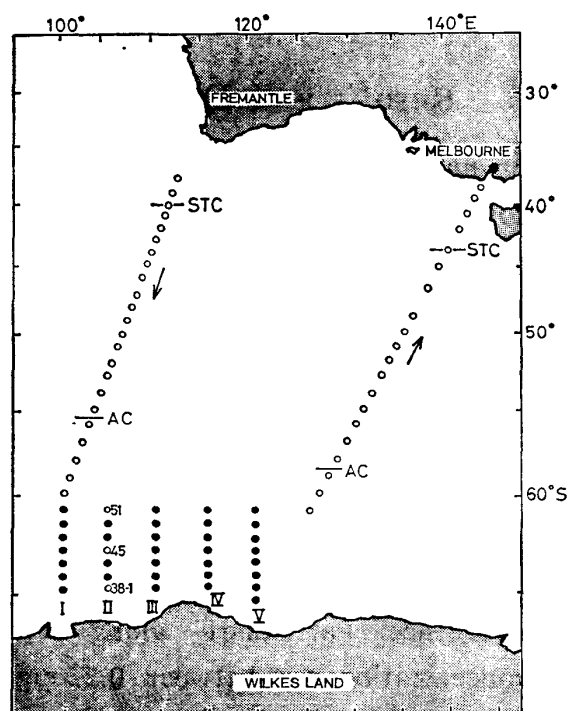


Fig. 1. Map showing the chlorophyll *a* measurement stations occupied by R. V. KAIYO MARU in the southern ocean during the period from 6 January to 9 February, 1980. STC; Subtropical Convergence, AC; Antarctic Convergence, ○; stations of surface observation, ●; stations in the survey area (61°–65°S, 100°–120°E).

cruise tracks of the KAIYO MARU and in the survey area.

## 2. Materials and Methods

The sampling stations are given in Fig. 1. The surface water was taken by the cloth bucket and the samples from 9 layers between 10 m and 200 m were obtained by Nansen bottles. The surface water samples on the outward and homeward legs were collected four times a day at 2:00, 8:00, 14:00 and 20:00 (local time). In the survey area, the observation sites were set at 5° longitude intervals (Fig. 1). Then, the sea water of 100 to 200 ml was filtered through a glass fiber filter (Whatman GF/C 47 mm in diameter) with the aid of a vacuum-pump. Pigments trapped on the filter were extracted with 90 % acetone solution by the use of an ultrasonic generator. After centrifuging the extract for 5 minutes at 3000 rpm, the amount of chlorophyll *a* and phaeophytin was determined fluorometrically according to the method reported by SAIJO (1975). A Turner Model-III fluorometer was used for the pigments determination. The intrinsic fluorescence values of phaeophytin and the acid factor were 5.13 and 1.8, respectively.

## 3. Results and Discussion

### 3.1. Surface observation on the outward leg

Longitudinal variation of the chlorophyll *a* content was observed on the outward leg from Fremantle to the station of 65°S, 100°E (Fig. 2a). The observation was done from January 7 to 15, 1980. The Subtropical Convergence and the Antarctic Convergence are assumed to be at about 40°S and 56°S latitude, by the data of temperature and salinity observations, which are given in 1979 KAIYO MARU Survey Cruise Report. Chlorophyll *a* increased to 0.29 mg/m<sup>3</sup> at about 46°S after a remarkable decrease (0.05 mg/m<sup>3</sup>) near the Subtropical Convergence. From 46°S to the Antarctic Convergence, chlorophyll *a* fluctuated between 0.12 mg/m<sup>3</sup> and 0.21 mg/m<sup>3</sup>, and the value increased beyond the Antarctic Convergence. Particularly along Section I of the survey area the chlorophyll *a* concentration was between 0.22 mg/m<sup>3</sup> and 0.44 mg/m<sup>3</sup>.

In the sea north of the Subtropical Convergence, in the Subantarctic region, and in the Antarctic region, the mean values of the chlorophyll *a* content and the standard deviations were  $0.13 \pm 0.00$ ,  $0.18 \pm 0.06$ , and  $0.25 \pm 0.10$  mg/m<sup>3</sup>, respectively.

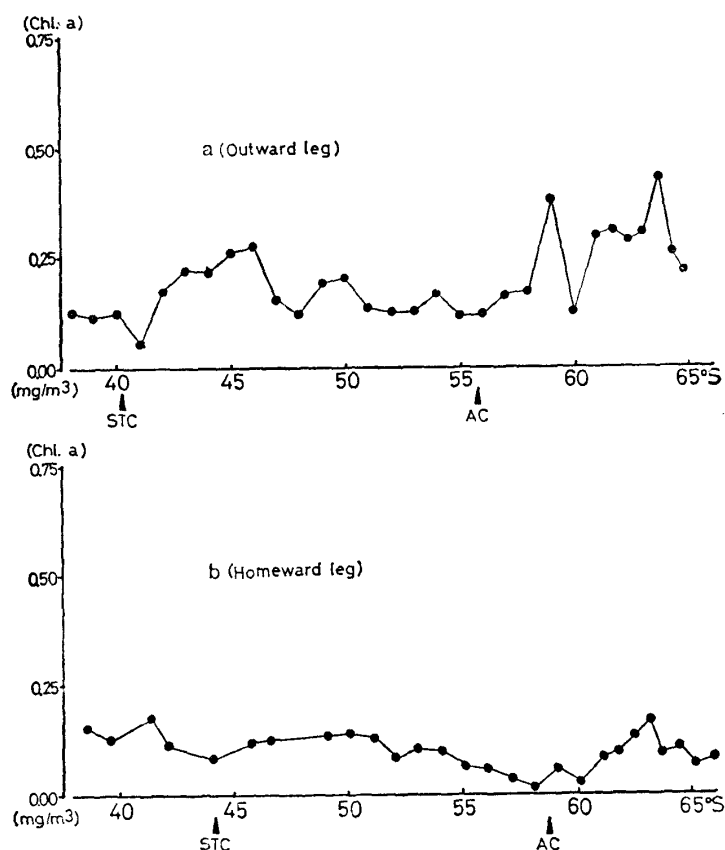


Fig. 2. Longitudinal changes of chlorophyll *a* on the outward (a) and homeward (b) legs.

### 3.2. Surface observation on the homeward leg

Longitudinal variation of the chlorophyll *a* content on the homeward leg from the station of 65°S, 120°E to Melbourne is given in Fig. 2b. The observation was done from January 27 to February 8, 1980. The Subtropical Convergence and the Antarctic Convergence were situated at about 44°S and 59°S latitude, respectively. The chlorophyll *a* concentration along Section V was lower than along Section I. The maximum value along Section V was 0.17 mg/m³. The chlorophyll *a* content remained at low level below 0.14 mg/m³ between the Antarctic Convergence and the Subtropical Convergence. The fluctuation of chlorophyll *a* was little except in the area near the Antarctic Convergence, where chlorophyll *a* value was 0.02 mg/m³. In the area north of the Subtropical Convergence it ranged from 0.09 mg/m³ to 0.18 mg/m³. The distribution pattern of chlorophyll *a* in the surface water on the homeward leg was quite different from that on the outward leg.

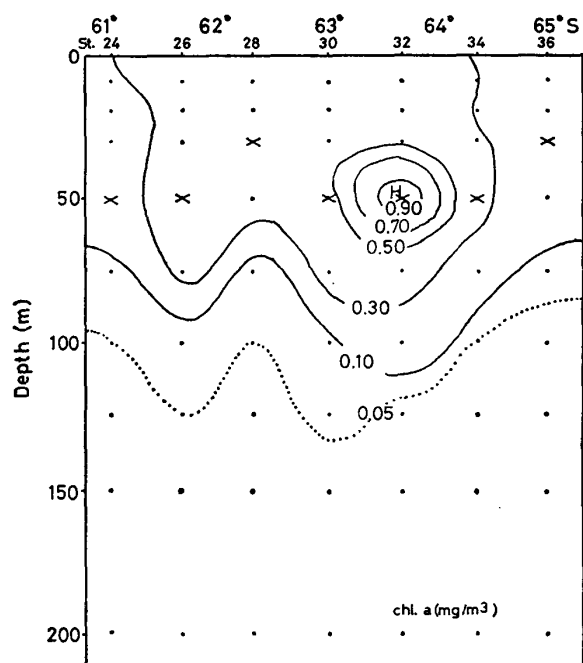


Fig. 3. Chlorophyll a profile along Section I.  
×; inflection point of sigma-t.

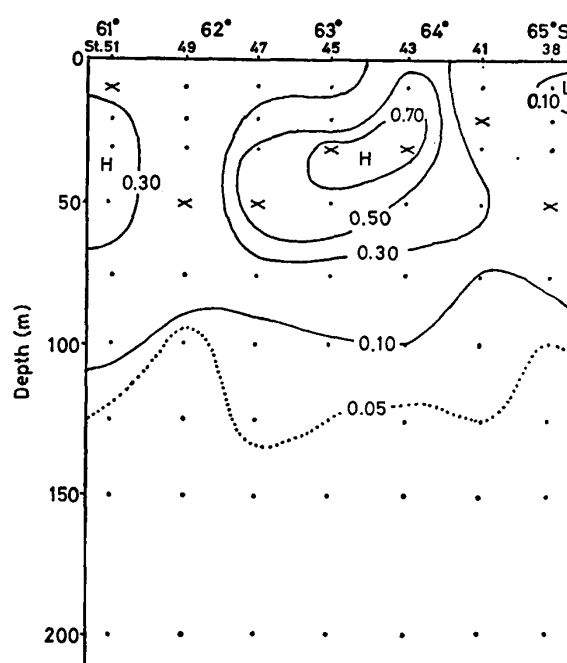


Fig. 4. Chlorophyll a profile along Section II.  
×; inflection point of sigma-t.

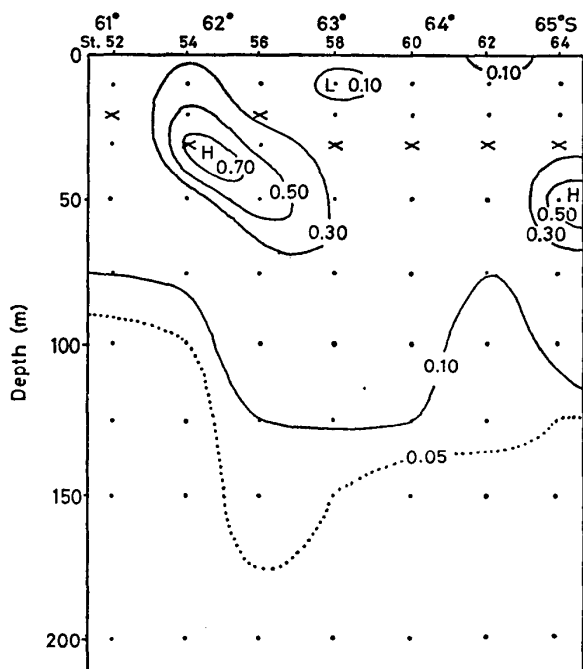


Fig. 5. Chlorophyll a profile along Section III.  
×; inflection point of sigma-t.

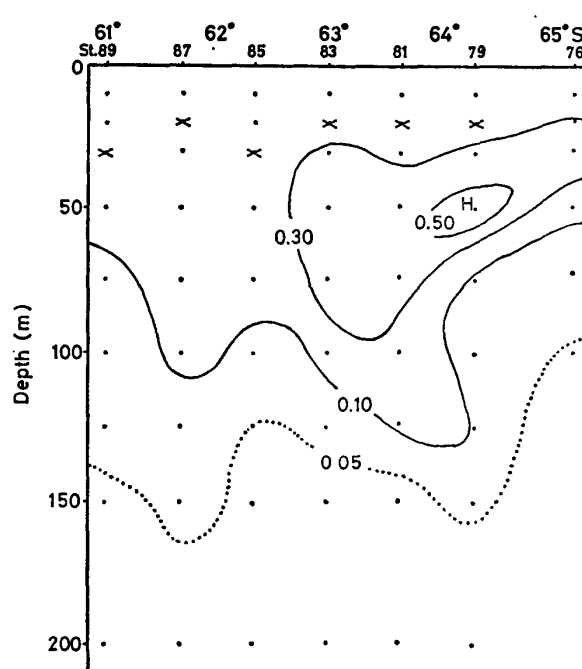


Fig. 6. Chlorophyll a profile along Section IV.  
×; inflection point of sigma-t.

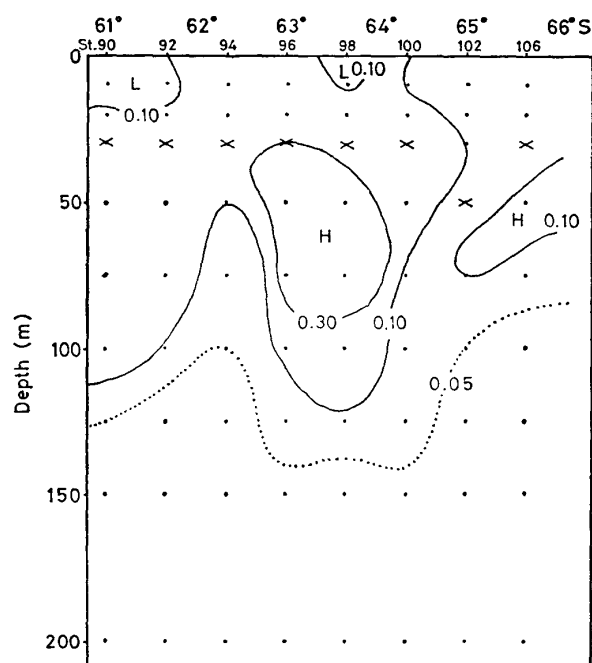


Fig. 7. Chlorophyll *a* profile along Section V.  
x; inflection point of sigma-*t*.

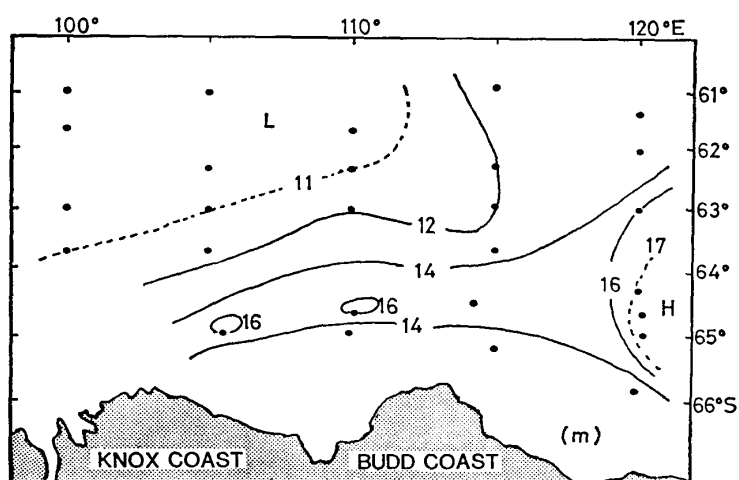


Fig. 8. Horizontal distribution of the transparency in the survey area.

The mean values of the chlorophyll *a* content in three water masses mentioned above, with the standard deviations, were  $0.14 \pm 0.03$ ,  $0.10 \pm 0.04$ , and  $0.10 \pm 0.04$  mg/m<sup>3</sup>, respectively.

### 3.3. Chlorophyll *a* profiles in the survey area

Chlorophyll *a* profiles along five sections are given in Fig. 3 to Fig. 7. Chlorophyll *a* concentration higher than 0.05 mg/m<sup>3</sup> was found above the depth

of 130 m, and it was hard to detect chlorophyll *a* in the waters deeper than 130 m. Chlorophyll *a* concentrated at the depth of about 50 m in Sections I and IV and at the 30 m layer in Section II and III. Water of high chlorophyll *a* over  $0.5 \text{ mg/m}^3$  was not found in Section V. High concentration of chlorophyll *a* appeared near  $64^\circ\text{S}$  in Sections I, II and IV, and near  $62^\circ\text{S}$  in Section III. The inflection points of sigma- $t$  are shown with crosses in Figs. 3 to 7. The water of high chlorophyll *a* concentration was found at the inflection points along Sections I, II and III. However, along Sections IV and V, it appeared below the inflection points. The highest chlorophyll *a* concentration ( $0.95 \text{ mg/m}^3$ ) was observed at the depth of 50 m near  $64^\circ\text{S}$  in Section I. The extent of the water of high chlorophyll *a* concentration became smaller toward east and the concentration of chlorophyll *a* decreased. The transparency was high in the southern part of the survey area and it increased toward east (Fig. 8). The reversed relation between the chlorophyll *a* distribution and the transparency is discernible in Fig. 3 to Fig. 8.

### 3.4. Distribution of pigment ratio

In general, the pigment ratio as shown by the percentage of chlorophyll *a* to the sum of chlorophyll *a* and phaeophytin can be used as an index of the activity of phytoplankton. The relationship between the pigment ratio and the chlorophyll *a* content was examined in the surface water and the water of 50 m depth at 10 stations between of  $61^\circ\text{S}$  and  $61^\circ40'\text{S}$  and at 10 stations between  $64^\circ20'\text{S}$  and  $65^\circ\text{S}$  in the survey area (Fig.9). At both layers, the pigment ratio of the southern stations was generally low compared with that of the northern stations. The result showed that phytoplankton was more active in the northern part. Furthermore,

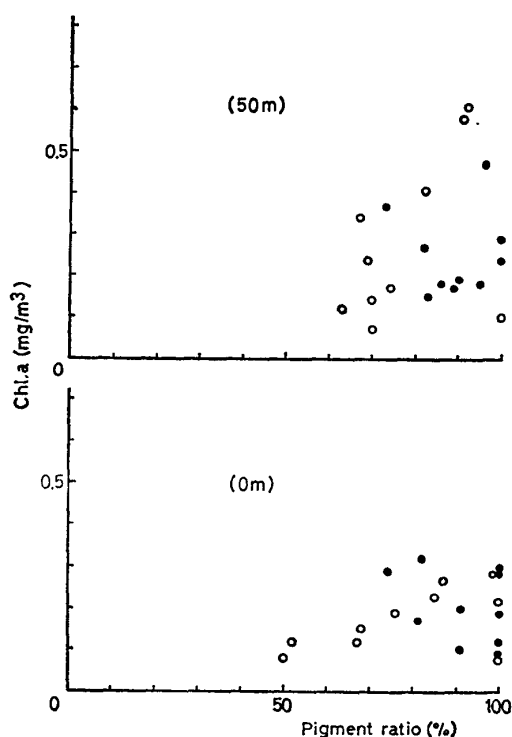


Fig. 9. Relationship between the chlorophyll *a* content and the pigment ratio in the surface water and the water of 50 m depth at the north (●) and south (○) sides of the survey area.

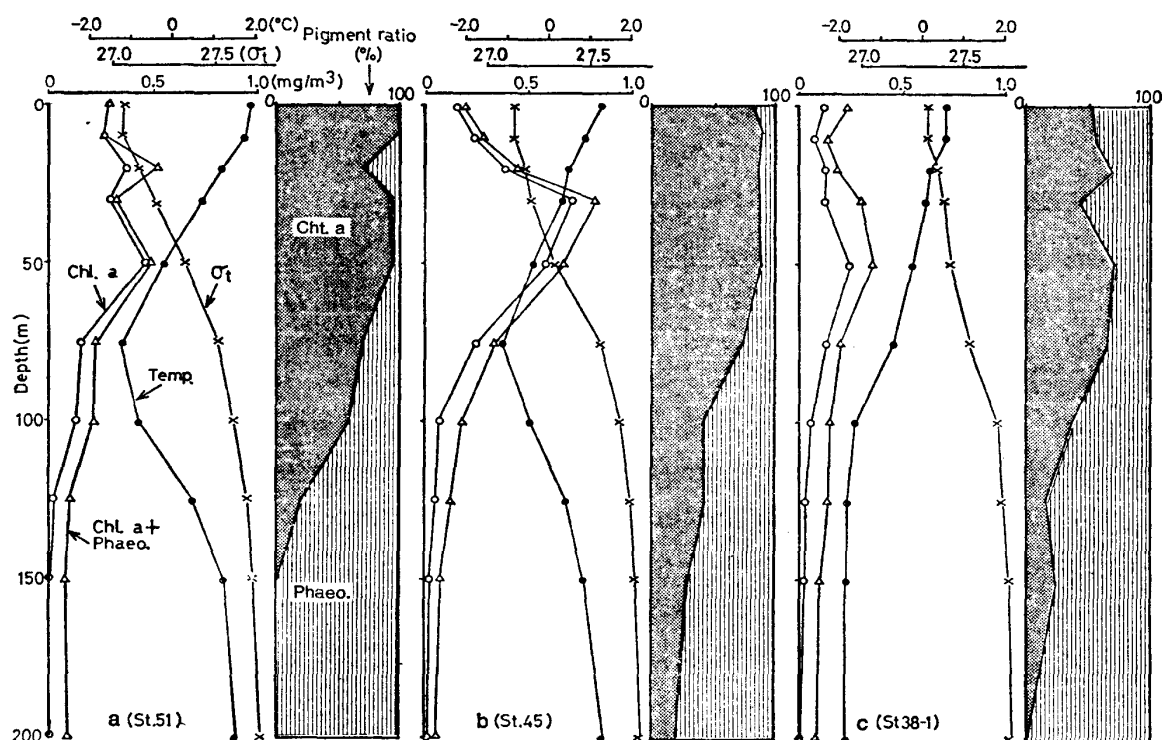


Fig. 10. Vertical distributions of chlorophyll *a* (○—○), chlorophyll *a* + phaeophytin (△—△), water temperature (●—●), sigma-*t* (×—×) and pigment ratio (chlorophyll *a*/chlorophyll *a* + phaeophytin); dotted zone. a; St. 51 (60°57.4'S, 105°02.3'E), b; St. 45 (62°59.7'S, 105°00.6'E), c; St. 38-1 (64°53.5'S, 105°07.6'E).

to know the vertical distribution of the active fraction of phytoplankton in the survey area, the vertical distribution of the pigment ratio was investigated at Sts. 51, 38-1 and 45, which represented north, south and intermediate stations. The results are illustrated in Fig. 10 with the profiles of chlorophyll *a*, phaeophytin, water temperature and sigma-*t*.

At St. 51 (Fig. 10a), a peak of chlorophyll *a* (0.47 mg/m<sup>3</sup>) was found at the depth of 50 m below which the chlorophyll *a* content decreased sharply. This layer corresponds to the picnocline. The pigment ratio was larger than 90 % in the layer of 0–50 m except 20 m layer, and it decreased gradually from the 50 m layer toward the deep. At St. 45 (Fig. 10b), the maximum value of chlorophyll *a* (0.71 mg/m<sup>3</sup>) existed at the depth of 30 m. This layer also coincides with the picnocline, below which the chlorophyll *a* content decreased remarkably. The pigment ratio was between 80 % and 90 % from the surface to the 50 m layer. It decreased gradually toward the deep. At St. 38-1 (Fig. 10c), the chlorophyll *a* content was lower than at former stations. It is distrib-



uted uniformly from the surface to the deep layer. The pigment ratio was approximately 50% at the surface and decreased with depth. KURODA (1978) reported that the pigment ratio in the Antarctic surface water ranged from 83 % to 91 %. This value almost coincides with those of St. 51 and St. 45, but is higher than that of St. 38-1.

The gradient of sigma-t was large at St. 51 and small at St. 38-1. The sigma-t gradient of St. 45 was intermediate between those of the above two stations. The profile of the water temperature of St. 38-1 differed from that of Sts. 51 and 45. In particular, the remarkable decrease in the water temperature of surface layer was recognized from north to south. From the vertical distribution of water temperature, sigma-t, chlorophyll *a* and pigment ratio, it was considered that in the southern most part of the survey area, the water mass might be unstable. From the longitudinal variation in the temperature of surface water, transparency, chlorophyll *a* concentration and pigment ratio in the surface layer, it was assumed that the surface water in the southern part of the survey area moved to north being warmed and that the phytoplankton was increasing in the water layer.

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